

Application No. 10/573,888
Amendment dated December 10, 2007
Reply to Office Action of September 12, 2007

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Docket No.: 80250(302741)

AMENDMENTS TO THE SPECIFICATION

On page 1, at line 4, please insert this subtitle as follows:

--BACKGROUND OF THE INVENTION--

On page 1, at line 5, please amend the subtitle as follows:

--Technical Field of the Invention--

On page 1, at line 13, please amend the subtitle as follows:

--Background Description of the Related Art--

On page 1, at line 4 please replace paragraph [0002] with the following:

--[0002] A conventional quartz waveguide type optical modulator is constituted so as to include a phase modulating portion, which provides a heater in the vicinity of an optical waveguide and varies the refractive index of quartz by heating, in the interference system. ~~Since~~ Because a refractive index temperature coefficient of the quartz, $1.1 \times 10^{-5} [1/^{\circ}\text{C}]$, is low in this constitution, a waveguide length (heater length) of about 970μ is required even if a temperature change of 50°C is allowed in order to cause the phase change of π in a communication wavelength of 1.55μ band. A time required for the temperature change is several 10 ms, and energy required for the temperature rise becomes 100 mW or more. Thus, there remains an additional problem such as an increase in crosstalk by thermal interference between modulators and an enlargement of a cooling mechanism. Further, it is reported that power consumption of the modulator is reduced by filling of groove structures in the optical waveguide with a material having a large refractive index temperature coefficient with the conventional art. (For example, see Non-patent Reference 1)

Non-patent Reference 1: Yasuaki ~~Hashidume~~ Hashizume, et al. "The Institute of Electronics, Information and Communication Engineers, General Conference, Lecture Papers, 2002," ~~March 27~~ March 7, 2002, C-3-10, P14--

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On page 2, at line 15, please amend the subtitle as follows:

~~--Disclosure Summary of the Invention--~~

On page 2, at line 16, please amend the subtitle as follows:

~~--Problem(s) to be Solved by the Invention--~~

On page 2, at line 17 please replace paragraph [0003] with the following:

--[0003] However, ~~since~~ because a heater portion position is away from the groove structure, the speed of the switching time is insufficient. Further, this structure is not applied to waveguide type lenses of which the focal length are variable and optical deflection type switches.--

On page 3, at line 7, please amend the subtitle as follows:

~~--Means for Solving the Problem--~~

On page 11, at line 1, please amend the subtitle as follows:

~~--Best Mode for Carrying Out the Invention--~~

On page 11, at line 5 please replace paragraph [0023] with the following:

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--[0023] Figs. 1A and 1B are views showing a constitution of an optical functional waveguide of a first embodiment of the present invention. Fig. 1A is a sectional view and Fig. 1B is a top view. The optical functional waveguide of the present embodiment includes: a substrate 11; a quartz waveguide clad 12; a quartz waveguide core 13; groove structures 14; a filling material 15; and a heater electrode 16. The optical functional waveguide serves as a phase modulation portion for optical modulators. The filling material 15 placed in the groove structures 14 is a transparent material in a wavelength region of guided light and is made of a different material or a material having a different composition from the quartz waveguide core 13. PMMA (polymethyl methacrylate), polyimide, epoxy resin, silicon resin or the like is applicable to the filling material 15. Alternatively, an organic material is applicable that hydrogen of these materials is substituted with fluorine. The refractive index temperature coefficients of these materials are generally about 10 to 100 times that of quartz. ~~Since~~ Because a refractive index temperature coefficient of quartz, $1.1 \times 10^{-5} [1/^{\circ}\text{C}]$, is low, a waveguide length (heater length) of about 970μ is required even if a temperature change of 50°C is allowed in order to cause a phase change of π in a communication wavelength of 1.55μ band. When the refractive index temperature coefficient of a material placed in the groove structures 14 is assumed to be fifty times that of quartz and the temperature change is 10°C , the length of a groove formation portion may be 184.3μ . For example, when the effective refractive index of the waveguide is 1.45, the average of groove widths is 9.7μ , the average of groove intervals is 9.7μ , the number of grooves is 10, and the refractive index variation is $\pm 2.75 \times 10^{-3}$, loss caused by outward reflection from the waveguide on each surface is only 0.00008 dB, and can thereby be disregarded. Loss caused by coupling to a radiation mode on an interface is about 0.5 dB. The heater electrode 16 is interposed between the groove structures 14 provided along an optical path in an alternating S-shaped arrangement so that the temperature of the filling material 15 can be quickly and sharply varied with small energy. The groove width of an optical propagation direction of the groove structure 14 is generally set to about 3 to 20μ . However, the groove width is required to be narrowed so that the loss can be reduced. The interval between the groove structures 14 is set to about 3 to 20μ . It is desirable for the groove width and groove interval to be randomly varied so that a minute resonance structure cannot be easily formed.--

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On page 15, at line 18 please replace paragraph [0030] with the following:

--[0030] Figs. 8A and 8B are views showing a constitution of an optical functional waveguide of an eighth embodiment of the present invention. Fig. 8A is a sectional view and Fig. 8B is a top plan view. The optical functional waveguide of the present embodiment includes: the substrate 11; the quartz waveguide clad 12; the quartz waveguide core 13; the heater electrode 16; groove structures 31; a filling material 32; and a quartz slab waveguide 33 constituted by the quartz waveguide clad 12 and the quartz waveguide core 13. The optical functional waveguide is not a single mode waveguide and serves as a phase modulation portion for optical modulators. The temperature of the substrate 11 is controlled and the refractive index of the filling material 32 is controlled. Each refractive index of the quartz waveguide clad 12 and the quartz waveguide core 13 varies, but the variation is so small compared to that of the filling material 32 that it can be disregarded. When the effective refractive index of the quartz slab waveguide 33 and the refractive index of the filling material 32 are the same at a certain temperature, light propagating through the quartz slab waveguide 33 is hardly affected. However, the refractive index of the filling material 32 relatively increases or decreases as the temperature rises or lowers, and thus the propagating light is subjected to convex lens operation or concave lens operation. As a matter of course, when the refractive index temperature coefficient of the filling material 32 is negative, the propagating light is subjected to concave lens operation or convex lens operation, respectively. Further, the focal length of the lens can be controlled by the temperature. Thus, a wavefront of the light propagating through the slab waveguide can be controlled by control of the temperature of the filling material. That is, a divergence angle of the propagating light can be controlled. The number of groove structures 31 are increased or decreased so that a control range can be designed. Especially, when reflected light or a resonance characteristic is required to be avoided, it is required that a boundary surface is tilted to an optical axis similar to the second to fourth embodiment. Thus, the reflected light or the resonance characteristic can be avoided to a considerable extent. However, in the present embodiment, ~~since~~ because the boundary surface of the top view is a curve, effects cannot be obtained even if the boundary surface is tilted. Therefore, a line indicating the boundary surface in the sectional view is tilted.-

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On page 20, at line 2 please replace paragraph [0035] with the following:

--[0035] Fig. 12 is a top view showing a constitution of a dispersion compensation circuit of a twelfth embodiment of the present invention. The dispersion compensation circuit of the present embodiment obtains the same characteristic as the eleventh embodiment with a reflection type constitution and includes an arrayed waveguide grating 71, more concretely, it includes: a slab waveguide 72; arrayed waveguides 73; a slab waveguide 74; a mirror 75; groove structures 76; and a filling material 77. The shape of the mirror 75 may be linear, but a circular mirror is generally employed which has a curvature suitable for control of a dispersion value when the temperature does does not vary. Loss in the present embodiment is larger than that of the eleventh embodiment, but the device size is miniaturized and an initial dispersion value can be set by the mirror curvature.--

On page 22, at line 2 please replace paragraph [0037] with the following:

--[0037] Fig. 14 is a top view showing a constitution of an optical functional waveguide of a fourteenth embodiment of the present invention. The optical functional waveguide of the present embodiment includes: single mode waveguides 91; tapered waveguides 92; a slab waveguide 93; and lens-shaped groove structures 94, and it is coupling portions of a slab waveguide and arrayed single mode waveguides, the coupling portions being frequently used for multiplexing/demultiplexing circuits. The lens-shaped groove structures 94 are provided so that light made incident from the slab waveguide 93 side into a gap between the single mode waveguides 91 can be introduced into the single mode waveguide 91 with high efficiency and loss of the multiplexing/demultiplexing circuit can be reduced. ~~Since~~ Because amplitude of light made incident from a slab waveguide varies depending on places (the amplitude is large in a central portion and small in an end portion), each interval between the first to fifth single mode waveguides 91-#1 to #5 (central intervals are narrowed and end intervals are widened) is adjusted and sizes of the first to fifth groove structures 94-#1 to #5 are adjusted so as to correspond to the intervals respectively, so that coupling efficiency from the slab waveguide 93 to the first to fifth single mode waveguides 91-#1 to #5 can be made equal to each other.--